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PALESTINE AS ILLUSTRATING GEOLOGICAL AND GEOGRAPHICAL CONTROLS.

BY

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The lack of vitality which has so long characterized the scholastic and collegiate study of geography is happily being replaced by the energy of a truly scientific spirit, and hence this science, the most nearly allied of all the natural sciences to everyday human interests, is bound to take its place as a higher branch of academic study. Geography is to be, like physics, a true science, wherein the facts it deals with are brought into the relation of cause and effect; and the recognition of this relation is, from the point of view of mental development, the most important phase of the study. In a word, the modern conception is that, just as we understand the French Revolution by following the currents of French and European life back along the many tributary channels of the foregoing centuries and on into the fuller life of this century, so the present geographical facts of a country attain an immensely greater interest when they are seen in relation to the past physiographic history of that region.

Viewed from this standpoint Palestine offers most suggestive material for discussion.

The dynamical geologist—he who conceives the forces of nature as at work in geological time—sees in Palestine a region in many respects without parallel on the earth, yet instructive, as it gives him the liveliest illustrations of the great changes that have occurred in other ages and in other parts of the globe. The scientific historian, on his part, boldly states that "for a philosophic mind—that is to say, for one engrossed in the origin of things—there are not more than three histories of real interest in the past of humanity: Greek history, the history of the people of Israel, and Roman history." This history of the inhabitants of Palestine is controlled by the physiography of the land; and, as we may believe that every man of culture should know much of the history, it follows, in our view, that he should have some knowledge of the land-forms and physical conditions. The following brief sketch is offered as a small contribution, intended to supply the need of a modern account of the geology and physical geography of this wonderful country. I say "modern," because I have tried to present an eclectic summary of the safest conclusions which appear within the pages of German, French, English and American geological and geographical writings of the last thirty years. The otherwise excellent memoir of Robinson is faulty, since, in the early sixties, the geology of Palestine was not determined in sufficient detail.

THE GEOLOGY.—The geological history of Palestine is relatively simple. Much has yet to be learned by way of supplement to the work of Lartet, Hull, Fraas and Diener, but we already know enough of the main chapters in the sequence of events to explain the existing relief of the country. I shall devote a possibly disproportionate share of the present paper to the discussion of this subject, so fundamental is it to an understanding of the physiography.

First of all, there is recognized in Syria, as in so many other parts of the world, a crystalline basement, on which the later formations rest. The determination of the exact age of these rocks is not yet complete, but we may be sure that they are geologically ancient, and that they bear witness to long-continued residence of the region under conditions of subaerial erosion. A complex of granites, diorites, porphyries and schists seems to extend, not only over Palestine, but into Arabia Petræa, the Sinaitic peninsula and Egypt. The savage scenery of the lofty granitic group in which explorers have tried to find the true Horeb, is developed on an area of the basement, which has been disclosed by the removal of the younger, overlying rocks. The deep valleys now sunk in the basement have been carved out by the perennial and intermittent torrents, and by the winds of the desert, according to laws of denudation similar to those that governed the disappearance of the cover. This island of crystalline rock, peering out from beneath the overlying thick sandstones and limestones, is a gigantic "outcrop" of the fundamental rocks of all that part of the world. Similarly exposed in numerous places, they have furnished the Egyptian at Thebes, the Phœnician of Tyre, and the Roman of Palmyra with the gigantic monoliths for their temples. It is an oft-repeated story how Cleopatra's Needle and the other sister obelisks of Egypt can be traced to the quarries of Assuan, near the First Cataract, where the Nile is busy hewing out its channel across the ancient rocks. This relation of markedly contrasting crystalline foundation and overlying blanket of uncrystalline sediments is exactly paralleled in Russia; the low plateau of Finland corresponds to Sinai, the rapids in the Dnieper below Kiev to the Nile cataracts, and the coarse red granite of Assuan to the beautiful variegated syenite of the lower Dnieper. Or again, there is an analogy with the vast fundamental complex of Canada in its continuation under Palæozoic formations to the crystallines of Missouri.

Excepting these rocks, which stretch far and wide over western Asia and northeastern Africa, we have no remnant of formations that may have been laid down during all the time from the Archæan to the Carboniferous period; that is to say, most of Palæozoic time, during which many of the terranes of America were in the making, was in Palestine occupied with processes of which we have no record beyond that one of enormous denudation. In this way was produced on the old granites and porphyries an uneven surface, far below the surfaces of strata which presumably overlay the crystallines.

The patches of Carboniferous limestone in the south and the more recently discovered areas of Jurassic limestone in Palestine, indicate that the region was, wholly or in part, submerged beneath the sea during those periods. A general submergence of the land during the Cretaceous and Eocene time followed, and it was then that the very thick limestones and sandstones were deposited which were later to compose the main massifs of Palestine. It would hardly pay us, in view of our main object and limited space, to go into details regarding the nature and succession of these sediments. Suffice it to say that they include the famous Nubian sandstone, which figures so prominently in the geology of Egypt and of the Sahara, and the no less famous Nummulitic limestone from which the Sphinx was carved and the bulk of the Pyramids constructed.

Let us imagine, then, our crystalline basement sinking slowly beneath the Cretaceous sea-level and continuing so immerged through most of Eocene time. The waste of the unsubmerged areas round about was sorted by river, wave and marine current, and by the same agencies laid down on the subsiding floor of the sea as sandstones, clays and marls; at the same time, there was an enormous accumulation of the calcareous tests and skeletons of corals, molluscs and other animals, the material of the future Palestinian limestones. There appears to have been no serious break in the succession of the deposits; on the contrary, there is peculiar difficulty in separating even the Cretaceous and the Eocene. They grade into each other in a manner not often exhibited elsewhere.

A simple condition this! The late Eocene sea covers horizontal marine strata in all several thousand of feet in thickness. We have now to note the most interesting event of all the geological history of Palestine, the formation of the master-lines in its topography. It is evident that there has been very great movement of the earth's crust since Cretaceous times, if we find the Cretaceous limestone on Hermon nearly ten thousand feet above the sea. There are two ways in which these movements may take place—either by the lateral accretion of rock-masses along lines of wrinkling in the crust, or by the massive uplift of the region, probably accompanied by massive subsidence in a neighboring district. The mountains of Pennsylvania, of Vermont, of British Columbia, the Alps, the Pyrenees, are familiar examples of the former kind of uplift; the plateaux of Colorado and of Utah illustrate the other sort; while the greatest uplifted massif of all those now existent on the globe, that of Tibet, combines the two methods on a titanic scale. In the language of the dynamical geologist, the movement of the crust in the one instance is "tangential" with respect to the earth's contour; in the second, it is "radial." In Palestine the chief motive in the establishment of the existing relief was radial movement. The cause of this change of level is one of the hardest nuts which the geological theorist has to crack; but we can safely leave that problem to him and use the indefeasible *fact* with its important consequences.

It is probable that even the Cretaceous sea-bottom was uneasy, for we find that certain lavas were extruded and deposited on the sea-floor at that time, and, as we shall see, lavas are strongly suggestive of dislocation and of movement whenever they appear in this region. Yet the main disturbance of which we need to take account occurred in late Eocene time or during the early Miocene. The studies of Palestinian geology do not permit of our dating the uplift more definitely, but, on reference to a chronological table of the geological formations, the reader will see that post-Eocene time is a relatively modern affair.

Now, what will happen to the massive marine sediments when they are upraised thousands of feet above the sea-level? It is possible to conceive that they might have come up without a serious modification of their almost perfectly horizontal surface, except for the carving it would undergo from the streams born upon that surface. But the fact was otherwise. The elevation of the mass meant strains, the natural result of the enormous power of gravitation, when it operates on such a great volume of rock. These strains or tensions proved too great for the strength of sandstone, limestone, granite or porphyry, and of the unknown rocks beneath them all, and relief was given by wholesale fracturings.

The German and French geologists tell us that the old-mountain plateaux of the Black Forest and Vosges, in western Germany, were formerly connected by an intervening belt of similar rock-masses of accordant altitude with the two massifs; that, by radial movement, the whole continuous plateau was gently arched with a north and south axis; and that the tension finally grew so great that the top of the arch dropped several thousand feet. In this fashion, an immense trough was opened between the more stable limbs of the arch ; these to-day form the Vosges and the Schwarzwald. No better summary of the process can be found than in the well-known metaphor, "the keystone of the arch fell in." A much grander illustration occurs in the long line of mountain blocks that represent, not only the keystone but many adjacent stones of an arch which nature tried to establish over what is now the Great Basin of the West. The breaking down of the potential arch left the Sierra Nevada as the western limb, the Wahsatch as the eastern limb, and the ridges of the "Rocky Mountains" as the ruins of the middle part. Doubtless, all my readers are acquainted with these results of the synthetic studies of Leconte and others—the résumé of one of the grandest events yet recorded on the earth. Yet we need a name for the great depression into which the keystone falls, and I shall ask to be permitted the use of a designation derived from the European case. We shall thus follow the Germans in calling a "graben" the depression between two stable massifs which are now separated from each other by the subsidence of a block along lines of fracture. There is something significant in the name "graben"—trench or moat—for the classic locality, since it was a military force that changed the "Vosges" into the "Vogesen."

It is not to be implied that a pre-existing fold or swell of the ground is necessary for the existence of a graben; the trough may be caused simply by the dropping of a block out of any mass of rock when the underpinning is too weak to support its weight. In the case of the Bekaa graben, in northern Syria, there was certainly no arching; authorities differ as to the fact of arching over the Ghôr, or Valley of the Jordan. Yet, either method of dislocation may produce essentially the same topographical forms, and, among them, a graben.

Very probably, there was nothing catastrophic in the formation of the Rhine graben; many thousands of years must have elapsed before the great trough was complete, and the "faulting" or slipping along the fracture-planes was usually too slow to have been followed by human observation. So it was in Palestine. The march of events was slow and dignified, worthy of the grand result. The simultaneous subsidence of the graben-block, and raising of the adjacent blocks, were intermittent; they persisted through part of Tertiary and Quaternary time, and may not be finished yet. Although the faults, or fractures along which movement has taken place are of various date, they have combined to produce a relatively simple effect on the form of the surface. This effect consisted in the development of a true graben between two plateaux; the "Ghôr," including the valley of the Jordan, the depression of the Dead Sea and the Wady el Arabah to the south, represents the graben; the belt of "mountains" from Lebanon to the Tîh Plateau in the Sinai peninsula, belong to the Western Plateau; and Hermon, the Gileads, the uplands of Moab and Mt. Seir bound the graben as the imposing Eastern Plateau.

The conspicuous nature of Carmel, with its bold promontory dropping off at the Mediterranean shore, has long given it a romantic place in the history of Palestine; from the days of Elijah and the struggle with the priests of Baal, to the time of Vespasian's visit at the no less heathen Roman oracle, and on to our time of the picturesque Carmelite monks. It is itself an uplifted, slightly transverse block, overlooking a minor graben, partly buried in the modern sediments of the alluvial plain of Esdraelon.

Simultaneously with the dropping of the Ghôr and Esdraelon blocks, there was the similar down-faulting of an immense block in the north which now bears in part the valley of the Orontes River. This graben, the Bekaa, separates Lebanon and Anti-Lebanon; with the faults representing its continuation, it extends to the mountainous plateau of Asia Minor, the folded rocks of the Taurus. These are of a totally different composition and history; they have been dislocated, not so much by faulting as by the intense plication of the strata transverse to the meridional trend of the grabens. On the south, the Palestinian graben is connected by fractures of common direction with the Gulf of Akabah, the northeast arm of the Red Sea. That gulf, which in places is as much as four thousand feet in depth, is to be regarded as a graben flooded by salt water. It seems tolerably certain that the basin of the Red Sea is also a graben, interrupting the once continuous crystalline platform of Arabia and Egypt; and that our graben-sinking does not stop here, but may be recognized in Abyssinia. Professor Suess, who has done more than any one else to emphasize the importance of radial movement, attributes the depressions of the great lakes of Central Africa to crustal deformations of the same order and of the same age as the Dead Sea faults.

It is not to be thought, neither was it to be expected, that the differential movement was of the same degree throughout the length of each graben; on the contrary, the intensity of the action was very uneven. In the north it was at a maximum, and Lebanon and Anti-Lebanon, even after the wearing of rain and torrent, are still the highest parts of the Syrian plateau. For a similar reason, the "mountains" of Moab and Judæa dominate all southern Palestine. It is interesting to note that in both regions these highest blocks are adjacent to the deepest parts of their respective grabens. Hebron lies 6,000 feet above the bottom of the Dead Sea, and the highest summits of Lebanon rise 5,000 feet above the valley of the upper Litani. The site of Nebo seems well chosen; for while it is situated close beside the deepest depression on any continent, it is so high that, from its summit, one can get an unimpeded view of all Palestine. With this fact in mind, the reader of Deuteronomy will understand how Moses, in the intensely dramatic last hour of his life, could see the farthest limits of the future possessions of his people. Yet these heights do not by any means represent the total amount of movement, because from the surface of the plateaux has been removed much material by the denudational processes, and in the grabens have been deposited much of their waste. In like manner Mt. Whitney looks down on Owen's Valley and the Telescope Range on that wonderful trench, two hundred feet below the sea-level, Death Valley of California; just as the loftiest coast ranges of the world, as a rule, flank the deepest abysses of the ocean. In all these cases it looks as if the extraordinary effort of the underground forces were compensated by the unusual degree of subsidence in adjoining areas.

It would take us too far afield to recount all the evidences of dislocation in Palestine; but the principal ones should be stated, since they refer to some of the most interesting natural phenomena of the country.

In the first place, the actual fault-fractures can be readily observed by one even little versed in the practical methods of the field-geologist. The chiefest of all occurs on the east of the Ghôr, and this one alone is of such magnitude as to explain almost the entire subsidence of the block on that side. On the western side, the graben-block was let down by a succession of lesser parallel faults, which have riven the plateau-edge into narrow blocks that step down to the Jordan in the manner of terraces. Outside of the great graben, many roughly parallel faults have been discovered, particularly in and about Lebanon, where the dislocations seem to be considerably more complex than in southern Palestine. One such fault doubtless explains the steep western slope of the Jerusalem upland. Furthermore, it is not by accident that the faults of Palestine have a direction common with that of the Levantine shore. This part of the Mediterranean did not exist in the early Miocene Age; that is, the region was dry land and became submerged in deep salt water only in late Miocene time or during the Pliocene. In fact, it seems probable that the Palestinian dislocations and the subsidence of the Levantine basin were, in a geological sense, synchronous. The irregular shore-line of the unsubmerged block has since been smoothed by waves and currents, the latter even bringing alluvial mud from the Nile to aid in the work.

Again, we have evidence of the gigantic nature of these earth-movements in the vast outflows of basalt, that commonest of lavas, on the surface of the uprising limestones. So profound was the influence of the fractures that they offered a means of ready escape for the molten, or potentially molten, rock which must exist beneath the oldest solid rock of the visible crust. Possibly nowhere else in the world is there to be seen a closer dependence of volcanic extrusion on the presence of great faults. The lavas northeast of Jerusalem, the numerous vents east of Carmel, west of Damascus and in Northern Syria, are, with few exceptions, grouped on lines of fracture which have been actually located. Where lies the greatest fault of all, we have the fissure from which issued, in part, the basalt of the Hauran plateau, with its thirty-five hundred square miles of lava; just east of the Dead Sea occur several important areas of a similar basalt. Just as the faulting lasted through much of late Tertiary time, so these lavas were erupted in a sequence that may have only ceased within the time of man's occupation of the land. So late are some of the flows that they fill valleys recently hollowed out of the limestone or out of the older basalt masses.

Still further, it may be contended that the faulting which has given birth to the grabens of Syria is not yet complete. From the days when the prophet Amos dates his book, from the "great earthquake" in the reign of Uzziah, king of Judah, to our own century, there have been many destructive earthquakes in Syria. These have been most destructive in the north, especially in the large towns, Aleppo, Antioch and others; but Palestine itself has suffered much damage. Now it is worthy of note that towns like Safed, which are situated on or near lines of fracture, have been more severely shaken than Jerusalem and other ancient towns that lie relatively remote from the more important faults. Almost whole populations have been destroyed in the towns and villages on the brink of the graben escarpment, the wonderful Greco-Roman monuments of Baalbec and of Palmyra have been levelled, while Damascus, old as it is, bears but few traces of seismic action. Does it not seem probable that the occurrence and distribution of the earthquake centres indicate a continuance underground of slipping along the fault-planes?

That the subterranean activity is not yet wholly extinguished is again demonstrated by the well-known springs of bitumen (asphalt), which are so numerous in this zone of dislocation. According to the best theory of the origin of bitumen, its constituents have been derived from the organic debris enclosed in the sedimentary rocks. Material of this sort, chiefly fossil-wood in the form of lignite, is abundantly distributed in the rocks of Palestine. It is carbonized by the heat of the deep-seated lavas which have still retained their heat; during the carbonization the volatile hydrocarbons are driven off, find their way to the surface through fissures, where they condense and issue as a liquid mixture that freezes into what we call bitumen. This substance so permeates the gravel and sand of the old alluvium of the Jordan Valley that it forms a veritable cement, comparable to the cement of our city pavements. Yet more important is its occurrence in beds, and these of the purest quality known; they are interstratified with the limestones, and their value may be gauged from the fact that one layer alone on the flanks of Hermon is eighty feet thick and of the purest quality. When the sleepy Turk gives place to men of western enterprise we shall have to undergo the shock of hearing of a Palestine mining boom.

The ancient name of the Dead Sea, "Lacus Asphaltites," is, in a sense, a summary of the last two arguments. In Roman times, as at irregular intervals ever since, masses of bitumen would occasionally rise from the bottom of the lake, buoyed up by the unique density of the water, although its own specific gravity is considerably higher than that of fresh water. Whether—as is likely—the mineral be now forming at the vents of springs at the bottom, or be simply enclosed in the rocks underlying the lake, its dislodgment from the bottom is most often effected by earthquakes. So impressed were Josephus, Pliny and other authors, that they have given us lively accounts of this peculiar phenomenon.

Waning volcanic activity in New Zealand, in the Yellowstone Park and in Iceland is evidenced by the occurrence of hot springs associated with the volcanic rocks of those countries. In Palestine such springs are numerous; and there can be no doubt that their high temperature is derived from not far distant hot masses of lava. Sulphuretted hydrogen is one of the chief substances dissolved in the waters of the springs; it explains the beds of sulphur on the shores of the Dead Sea, for they are the result of the oxidation of the gas on exposure to the air and surface conditions. But a greater interest attaches to other ingredients of the complex water, particularly to the bromine, potash and magnesium salts. These are present in such quantity in the Dead Sea water, that it is impossible to explain its salinity by mere evaporation of the river-waters which enter the lake from the Jordan and other streams. It is reasonable to suppose that the peculiar salt-content of the Dead Sea is the result, not only of the evaporation of surface waters, but also of the addition of these other salts in abnormal quantity from the copious mineral springs.

Finally, not only have we proofs of graben-sinking in the existence of actual faults and fractures, and in the resulting volcanic activity; there is evidence to show that the crust of the earth is even now, or has been very recently, undergoing slow vertical movement. West of the plateau of Judæa and Samaria lies a long, narrow strip of modern marine sediments, characterizing a series of raised beaches, extending from northern Syria to Cairo. The uplift has been unequal, but measures two hundred feet in many places. The shore-line itself is bordered by a belt of sand-dunes travelling slowly eastward at the behest of the westerly winds. The rich plains of Philistia and of Sharon are, in part, underlain by these deposits, in part by the land-waste of the plateau on the east.

In résumé, it may now be stated that Palestine possesses a fairly simple geological history, whereby there has been developed one of the most imposing grabens yet demonstrated. The southern part of the Syrian graben between the Lebanons is structurally in close relationship with that of Palestine proper, and the two together run significantly parallel to the shore of the Mediterranean, the eastern extremity of which is located over a dropped block. To the west of the graben lies a long, elevated zone of stratified rocks, characterized by the true plateau structure, that is, with the strata not seriously disturbed from their original horizontal position, although broken asunder by more or less vertical faults. Between the plateau and the Levant is a coastal plain. On the east of the graben is a second plateau, not to be distinguished in any essential of structure from the western, but bearing on its back thick and broad blankets of basalt. With these facts clearly in mind we may now proceed to the interpretation of the drainage, topography and climate of Palestine.

THE DRAINAGE.—In a general way, and in most of its details, the arrangement of the Palestinian streams could be deduced from what is known of the succession of geological changes in the province. From the moment the Eocene sediments were raised above the sea they were attacked by rain and rivers, and the deepening of valleys progressed during the long period of block-faulting. There must be a constructional water-divide on the Western Plateau and another on the Eastern. From the former will flow certain streams toward the Mediterranean in consequence of the uplift of the plateau limestones above the sea, and others toward the graben of the Ghôr, or that of the Bekaa, in consequence of the sinking of the blocks. Into the grabens will also be gathered the constructional drainage from the limiting escarpments. The wont of all streams is to lengthen their valleys by gnawing slowly headward, with especial rapidity where the headwaters follow the lead of soft rocks, which permit of easy excavation. The river-valleys of Palestine are of either of these two categories: they are directed down the slopes of original uplift, or they are the result of subsequent erosion on weak strata. Due rather to the lack of time sufficient for the lengthening and adjustment of subsequent streams than to the lack of contrast of hard and soft in the terranes of the plateaux, most of the trunks and branches of the rivers of all Syria belong to the former class.

The Orontes and the Jordan ideally fulfil many of the conditions which we are led to expect as to the early drainage of a graben. Their waters are compelled to flow in the trend of the bounding fault-scarps, they are collected in lakes where the graben is locally deepest, and they overflow from the depression where they are abundant enough to reach the lowest point in the wall of the trench. Yet there is one important feature of these rivers which may be termed accidental, since it is not characteristic of the normal series of events in the development of graben drainage. During the glacial period of northern Europe, long anterior to written or archæological records of man s existence in Palestine and contemporaneously with the so-called pluvial period, when the Sahara was swimming with floods of heavy rains, the whole of the Ghôr, from Lebanon to the divide between the Dead Sea and the Gulf of Akabah, was covered with the fresh waters of a great lake, which emptied, *via* the Wady el Arabah, into the Red Sea. At this time were deposited the thick lacustrine sediments which fill, to a depth of more than two hundred feet above the present river, the graben from the lake of Tiberias to the Dead Sea. The smooth floor of the Bekaa is the product of alluviation during the same period. Subsequent desiccation did not prevent the Orontes from keeping open its path to the Mediterranean, but with diminished precipitation the drainage of the Ghôr has become completely landlocked, and the Dead Sea cherishes the saline remnant of the water which is not evaporated by the sun in this sub-tropical region. In all respects the case is parallel to the history of another vast fresh-water lake located in the depression of a complex graben, and expanded by the heavy rains of a pluvial period, and by the melting snows of glaciers. I refer to the justly celebrated Lake Bonneville, which, by a change of climate, has shrunken into the Great Salt Lake of Utah.

The desiccation has given both Orontes and Jordan a chance to cut into and remove the lacustrine fillings, in which they have formed a series of magnificent terraces. With the relatively great average slope of ten feet in a mile, and frequent locally much steeper slopes, the Jordan is amply qualified to do this work, yet the numerous waterfalls in its course show that the bed of the river is not graded. Such a condition is in striking disaccord with the fact that the stream meanders excessively over the part of its course between the two larger lakes; as far as I am aware, meandering in this degree on so steep a declivity is recorded nowhere else.

Is it not strange to reflect that this active river, rivalling an Alpine torrent in its impetuosity, is, for most of its length, below the ocean-level, where the barometer stands at thirty-two inches and the surface of the water is more than a thousand feet below the Mediterranean? The rapidity of the current, notably in time of flood, may have been the reason why the people of Israel dreaded its passage more than the toilsome scaling of the cliffs to left and right. So quick is the flow of the Orontes that the Arabs, in truly sympathetic style, call it "The Rebel." Thus, in spite of the alluviation of their lower courses, and in spite of the fact that the lacustrine filling conceals the channels which may have been wrought out of the limestones before the climatic accident, we must believe that these rivers are still geographically young, and that they have much down-cutting yet to accomplish before they attain the gentle grades of streams that have been long at work. This is another indication of the fact that the graben-sinking was geologically recent.

The chief motive in the shaping of the graben stream-courses has been crustal deformation; but for the origin of valleys leading westward across the plateau to the Mediterranean, stress must be laid on the erosive activity of streams. The success of these dissecting agents may be measured by the fact that the fault-riven, but still more or less continuous plateau, has been carved into a succession of hills and greater massifs, the "mountains" of Hebrew and Arab writers. The work to be done was necessarily considerable; at the same time the streams have been handicapped, for they are not perennial. They are intermittent for two reasons. On the one hand, the rainfall, even here on the plateau, is too small for their needs; on the other, the nature of the rocks on which they flow forbids the concentration essential to perennial flow. These rocks are chiefly limestones, that is, rocks that readily dissolve in rain-water. To its solvent action is due the infinite honeycombing of the plateau by widening fissures, pipes and caverns extending deep beneath the surface. The limestones thus compose an enormous sponge that drinks up the rain-water which, by leakage and by actual subterranean brooks, finds its underground way toward the sea. Many of the hidden streams issue at the surface before reaching the shore, and hence we have a multitude of springs and fairly constant brooks rising a short distance from the coast. The frequent failure of one of these has given rise to the myth of the "Sabbatical River" of Pliny and Josephus; according to the former the stream runs only six days out of seven, according to the latter it flows only one day in the week. The upper valleys, largely the work of wet weather streams, are distinguished as "wadies," from valleys occupied by running water all the year round.

The caverns due to underground solution of the limestone have played a prominent part in the occupation of the country by man. Palestine has had its prehistoric troglodytes. The Horites, who were the forerunners of the Canaanites there and in Edom, were possibly cave-men. We doubtless owe the many references to caves in the Old Testament to such natural retreats capable of effective fortification; among others the cave of "Adullam" singles itself out, since it was thither that David fled from the king of Gath to gather together his little army of debtors and malcontents. Whether or not his conduct there was such as to warrant the sobriquet of "bandit" from Renan, the record shows that from this time forth he was able to command the resources necessary for the reconstruction of the monarchy in Israel. At the present time these caves, supplemented by artificial excavation, house the hundreds of hermits and ascetics who are grouped in the great lauras of the cliffs from Moab to Galilee: we have an example in the famous convent of Mar Saba, clinging to the precipitous cañon-wall of the brook Kedron.

There is one remarkable exception to the scheme of drainage that I have outlined. On reference to a good map of northern Palestine the reader will observe that the Litani River, instead of rising on the plateau, finds its source in the graben of the Bekaa, and then, at a level of about seven hundred feet above the sea, plunges boldly into the southern spur of Lebanon, which is here twenty-four hundred feet high. Crossing the massif, in a deep cañon, the river enters the sea near Tyre, thirty miles or more to the westward. Thus from the source nearly to the right-angled turn in its valley the river looks like a stream of overflow from the graben, like the Orontes; below the turn it has the position of those rivers that flow down the western slope of the plateau from the constructional divide.

This is not the place for the discussion of the probable origin of the river, but the various theories proposed may be stated. Two of these are due to Professor Diener. According to the first the valley of the Litani existed *before* the graben-faulting, and in proportion as the plateau-block was raised with reference to the graben-block, the river deepened its channel; in the modern nomenclature the Litani would then belong to the class of "antecedent" rivers. The second possibility, emphasized by Diener, is that the upper valley is in fact a valley of erosion, and thus the Litani has been let down to its present position just as the rivers dissecting the Wealden Dome of England have developed on the soft rocks of the inner lowland longitudinal valleys which are continuous with the transverse valleys. There are many patent objections to the second hypothesis and there are difficulties in the way of accepting the first. On the other hand, a third theory, which was rejected by Diener, seems to me to be the most probable of all; Thomson suggested it fifty years ago.* In brief, the lower course of the Litani may be regarded as one of the consequent streams of our western plateau which has captured the head-waters of the Jordan. The Bekaa is separated from the Ghôr in one place by a low divide that seems to be located in the bottom of an ancient abandoned river valley, through which the Jordan was formerly supplied with the overflow of the southern half of the Bekaa. Near the Bridge of Burghuz the Litani tapped the Jordan and led its Bekaa feeder out to the Mediterranean. Professor Diener could not favor this theory, because he failed to find the soft rocks guiding the lower Litani in its headward gnawing to the point where the Jordan was successfully endangered; he concluded that the valley ought, on this supposition, to have lengthened headward on the belts of soft sandstone which run athwart the Litani's course. But he does not seem to have considered the possibility that the limestone, on account of its solubility in water and of the systems of joint-fissures which traverse the rock, may in reality be less resistant to the headward growth of the stream than the sandstone. In view of the remarkable narrowness of the gorge just where the Litani pierces the plateau above and below Burghuz, and because of the existence of a natural bridge at El Kuweh, which Lynch, at least, considers as being composed of rock in place and not of masses fallen from the cliffs above, as well as for reasons which I shall here not attempt to detail, I venture to suggest that the capture took place by the solution of the much-jointed limestone in the divide, and by the resulting subterranean drainage of the graben through the Lebanon spur to the older Litani valley. Following the capture came the rapid degradation of the channel and the falling in of almost all the roof above the buried intermediate course of the river. That the capture was very recent is suggested by the extreme swiftness of the current and by the irregularity of the cañon bottom.

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* Bibliotheca Sacra, Vol. III, 1847, p. 205.

(*To be continued.*)